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RESOURCE USE AND SUSTAINABILITY: COMPARATIVE ANALYSIS BETWEEN THE USA AND THE REST OF THE WORLD

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ABSTRACT

Achieving sustainable resource use and ensuring that the flows of resources are managed in an effective and sound way through the economic system is critical, not only from an environmental perspective but also from an economic and trade perspective. Employing the IPAT methodology, data on Gross Domestic Product (GDP), population, Domestic Materials Consumption (DMC), and Domestic Extraction (DE) covering the period 2000 to 2017 were obtained to conduct an analysis on the pattern of material consumption between the USA and the rest of the world. The analysis finds that resource use declined in the USA during the period 2000 to 2017 while it increased in the rest of the World during the same period. Both USA and the rest of the World are experiencing ecological overshoot thus indicating the need for mixed of robust policy actions to save the planet while fostering economic development. Population, economic growth and urbanization were identified as key drivers of the rise in resource demand and consumption globally with China, India, and Japan contributing significantly to the rise in global resource use. Finally, the research established that the demand and consumption of carbon, fossil fuel and biomass have risen substantially across the globe as a result of the increasing need for energy to facilitate industrial activities which were on the rise in emerging economies, especially, China, Japan and Latin America.

Key Words: USA, World, Ecological footprint, sustainability, Gross Domestic Product, Domestic Materials Consumption, Domestic Extraction

INTRODUCTION

The use and management of resources matter for economic development and the sustainability of the planet. Natural resource form part of the natural capital and provide raw materials, energy, water, air and land, and support the provision of environmental and social services that are necessary to develop man-made, human and social capital. Resource efficiency and sustainability are crucial for social and human development and are part of several policy issues that need to be addressed by governments (OECD, 2008).

The consumption of resources including human appropriation poses several environmental, economic and social consequences that often extend beyond the borders of individual countries or regions. This has a bearing on decisions cutting across many policy areas, ranging from economy, trade and technology development to natural resource and environmental management, and to human health. Hence, resource use and governance should be a top policy agenda for governments.

The scarcity of natural resources has become a real possibility in the wake of the growing rate of industrialization. There is even growing competition for the control and use of natural resources (Schaffartzik et al., 2014; Giljum et al., 2014b). Global human economic activities are requiring more natural resources than ever before while globalization connects diverse and distant regions of the world through international trade, and emerging economies are increasingly claiming part of the natural resource pie to foster their economic growth and transformation (UNEP, 2011; Wiedmann et al., 2015).

Over the last decades, there has been an increase in the use of natural resources across the globe while little efforts have been applied to enhance the reproductive capacity of the planet (Hotta and Visvanathan, 2014). The increase in the use of natural resources is largely due to the increasing economic activities across the world including the rise in the middle class in several parts of the world (Yuk-Ha Tsang, 2014). The rise in the use of natural resources often raises serious concerns relating to sustainability and natural resource use equity.

Achieving sustainable resource use and ensuring that the flows of resources are managed in an effective and sound way through the economic system is critical, not only from an environmental perspective but also from an economic and trade perspective. Unsustainable consumption of resources has damaging consequences including resource depletion, climate change and economic recession.

This paper aims to critically analyse resource use to provide insightful information on the drivers as well as the economic, social and environmental implications. A comparative analysis of data on several resource sustainability indicators between the United States of America and the globe covering the period 2000 to 2018 will be conducted. The analysis on resource consumption and sustainability indicators provided in this paper will offer useful information for policy development and implementation aim at enhancing resource use and management.

DISCUSSION OF KEY RESOURCE SUSTAINABILITY INDICATORS

Several resource sustainability indicators have been developed over the years to measure the use and sustainability of natural resources. This research focuses on analyzing the critical resource sustainability indicators that are consequential for informing economic policies and industrialization efforts. Additionally, the indicators are establishing benchmarks for gauging climate change mitigation actions across countries. Hence, these indicators are some of the most essential tools for monitoring policy and international efforts for improving efficient use of resources as well as sustainable resource management.

Materials Flow Account Indicators

An analytical methodology of accounting for resource inputs, extraction and consumption, Material Flow Analysis/Accounting, is used to quantify flows and stocks of materials in a well-defined system (Hotta and Visvanathan, 2014). The methodology is applicable at the macro, meso and micro levels and can also be applied to products of different kinds including substances or materials. Material Flow Accounts (MFA) provides relevant information on material inputs and outputs of an economy(Fischer-Kowalski et al., 2011) and can be used for environmental planning and policy making.

There are three key indicators associated with MFA. They include Domestic Extraction (DE), Domestic Material Consumption (DMC) and Material Footprint. Two of the indicators, DE and DMC, can be considered territorial indicators or production-based indicators. These indicators measure the annual tonnage of aggregate materials flow which includes biomass, fossil energy carriers, metals and non-metallic materials through countries and are relevant indicators for gauging pressure exerted on the environment by a country (OECD, 2008).

DE measures the flows of materials that originate from the environment and physically enter the economic system for further processing or direct consumption (Hotta and Visvanathan, 2014). DMC measures the total amount of materials used in an economy or country and can be considered as the annual quantity of materials extracted from a country’s territory, plus all physical imports, minus all physical exports (Eurostat, 2012). It does not measure materials used upstream in traded goods and services. DMC does not only measure materials used in an economy but also the domestic waste potential of an economy (Weisz et al. 2006). The indicator reveals the amount of materials that becomes wastes in an economy. Material footprint, on the other hand, is a consumption-based indicator and includes all upstream raw materials associated with imports and exports. Material footprint quantifies all the materials involved in an economy’s final demand (Wiedmann et al., 2015).

Ecological Footprint Account

The ecological footprint indicators are essential sustainability indicators used for quantifying the impact of human activities on the ecosystem. The indicators are account-based indicators developed on the premise that Earth has a finite amount of biological capability that supports all life on it (Wackernagel et al., 2018). Ecological footprint is globally recognized as a key measure of environmental sustainability which provides an integrated, multi-scale approach to tracking the use and overuse of natural resources, and the consequent impacts on ecosystems (Mancini et al., 2018) and biodiversity (Galli et al., 2014).

The ecological footprint indicators add all human activities that require a bio-productive area and do not direct development (Steffen et al., 2015).Taking the ecological footprint as an accounting system instead of a normative indicator of progress provides an opportunity for the framework to be applicable across all context (Sala et al., 2015). This makes the Ecological Footprint relevant across a wide range of sectors and socio-political entities, each with their own unique cultures, natural systems, and methodological approaches to sustainability solutions.

The most widely used application of ecological footprint accounting is the National Footprint Accounts (NFA), initiated by Wackernagel et al. (1997). NFAs provide annual accounts of bio-capacity and the Ecological Footprint for the world and all countries. Since 2003, Global Footprint Network has served as the steward of the NFA and the underlying calculation methodology for the Ecological Footprint of countries (Wackernagel et al., 1999; Wackernagel and Rees, 1996), and has continuously implemented advances in science and accounting methodology into each amendment of the NFA (Boroucke et al., 2013; Lazarus et al., 2014).

Carbon Emissions

The emission of greenhouse gases and other dangerous gases into the atmosphere has damaging effects on the environment and the climate. Developed and industrial countries have contributed significantly to the emission of dangerous gases into the atmosphere due to the increasing industrialization and manufacturing activities which emit tons of dangerous gases into the atmosphere. A profound and widely recognized consequence of the emission of large volume of dangerous gases into the atmosphere is changes in climatic conditions.

Changes in the climate have significant negative effects on the environment which in turn affect almost every aspect of life. Climatic changes also threaten the existence of life on earth and its perilous effects have been experienced across the globe. In order to address the underlying causes of climate change and save the environment, leaders across the world have called for reduction in the emission of dangerous gases into the atmosphere and have encouraged and supported responsible and clean production, including investing in new technologies and renewable energy solution projects.

The key indicator of carbon emission is carbondioxide (CO_2). CO_2 emissions have been checked, monitored and quantified by the International Energy Agency (IEA). The IEA has developed a significant dataset for CO_2 emissions emanating from energy use covering 150 countries (IEA, 2020). Taking into consideration the importance of energy consumption on the environment, the data and analysis on CO_2 emissions will assist in understanding the trend of CO_2 emissions between the United States of America and the rest of the world.

METHODOLOGY

The United States of America was chosen for this analysis given its status in the world's economy and the availability of environmental data for the United States of America. Using Gross Domestic Product (GDP) as a measure for growth and development, the United States of America (USA) has the highest GDP in the world based on the data provided by the World Bank in 2020.

In order to conduct an analysis on the pattern of material consumption between the USA and the rest of the world, data on GDP, population, DMC and DE was obtained covering the period 2000 to 2017. Additional data on the different type of materials, such as biomass, fossil fuel and metal ores were obtained so as to enrich the analysis. Unfortunately, data on DMC for the rest of the world was not available. The periods for which data was collected represent the most recent years for which statistical data on the aforementioned indicators were available.

There are several drivers of environmental pressure and specially, materials consumption within an economy. In order to understand the pattern of material consumption, it is very important to understand the underlying drivers of materials consumption. Lamb et al. (2014) identified three broad and overlapping categories of drivers of environmental pressure, and they include the following: economic drivers represented by income and active population, demographic drivers represented by urbanization and population density, and geographic drivers represented by climate and bio-productivity of land.

Economic drivers were found to have significant impact on environmental pressure, specifically, materials consumption (Teixidó-Figueras et al., 2016). In their analysis of the distributional patterns of environmental inequality, Teixidó-Figueras et al. (2016) found that economic drivers accounted for 26% of the distributional pattern of DE, 49% of the distribution pattern of DMC and 55% of the distributional pattern of Material footprint. Given that DMC is consumption-based, an increase in income and active population contributed to an increase in the distributional pattern of DMC.

Income, measure by GDP, is a key measure of the level of economic activities of countries and is widely used by economist and international organizations for measuring a country's level of economic activities. Income is therefore considered the key macro-driver of environmental pressure (Rosa and Dietz, 2012). A higher GDP per capita suggests higher consumption and hence, higher resource use, while also, increasing economic activity increases pressure on the environment. Active population, represented by the fraction of the population, age 15 to 65, drives environmental pressure as this segment of the population consumes more than populations with larger fraction of children and elderly, and therefore, significantly contribute to higher productivity through labour supply thus increasing environmental pressure (Zagheni, 2011; Lugauer et al., 2014; O'Neil et al., 2010).

Identifying the drivers and their specific contribution to material use is very essential to this analysis. Therefore, the analysis employed the IPAT equation to analyse the key drivers of material consumption for the USA and the global economy. The IPAT equation, developed by Elhrlich and Holdren (1971), is essential for identifying and assessing the drivers and their specific contribution to materials use. Like Schandal and West (2010), environmental impact (I) is defined as material use represented by the indicator, DMC; Affluence (A) is defined as income and is represented by GDP per capita (US$ at constant prices) and Technology (T) is defined as material intensity and is represented by DMC/GDP. A logarithmic form is used to transform the IPAT equation so as to assess the individual contribution of the key drivers of materials use (Herendeen, 1998).

In order to measure the impact of human activities on the ecosystem, ecological footprint data was obtained for the USA and the rest of the world. The data covered the period 2000 to 2016 and represent the latest data on human appropriation and the carrying capacity of the earth. The key components of ecological footprint to include built-up land, carbon, forest products, and crop land will be analysed. The key drivers of ecological footprint, population, urbanization and GDP, will be analysed to inform the discussion on the pattern of ecological footprint in the USA and the global economy.

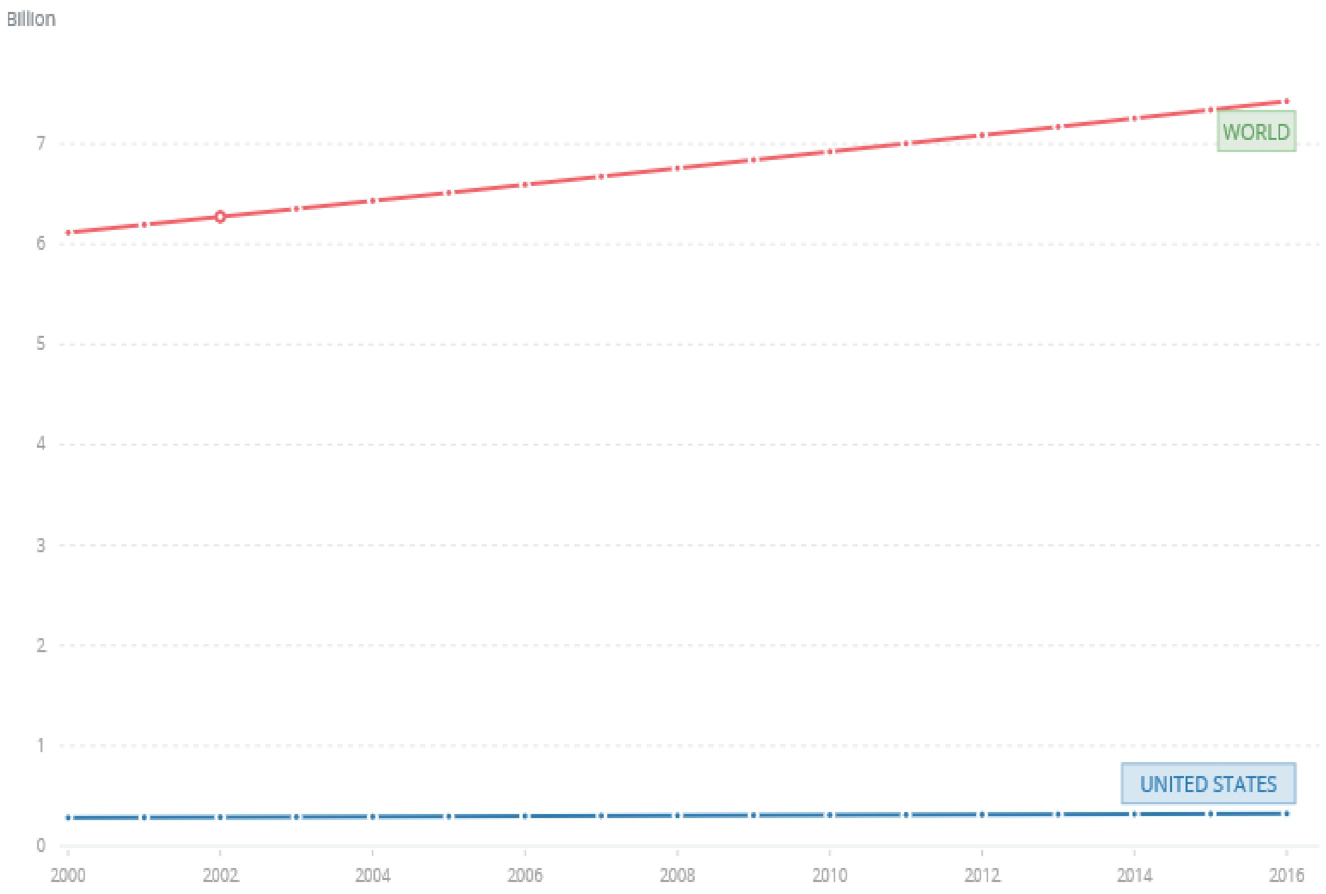
A critical pollutant of the atmosphere is CO_2. Data on CO_2 emissions was obtained for the USA and the rest of the world. The data covered the period 2000 to 2017 which reflect the latest data available on CO_2. The data on CO_2 emissions is essential as it will provide information on the trend of CO_2 emissions which should inform policy prescription and environmental planning strategies. A number of factors influence CO_2 emissions including population growth, GDP and energy supply (IEA, 2020). A careful analysis of these drivers of CO_2 emissions will provide better understanding and information for policy development and implementation.

MATERIALS CONSUMPTION DATA AND ANALYSIS

Below are graphs and tables that provide data for critical and comparative analysis of materials consumption in the USA and the rest of the world. The data include GDP, Population growth, DMC and DE total. Additional data on materials consumption components to include biomass, fossil fuel and metal ores are included in the analysis. The data covered the period 2000 to 2017 and represent the latest data on the aforementioned indicators. The data were obtained from credible sources including the United Nations Environment Programme (UNEP), OECD and the World Bank.

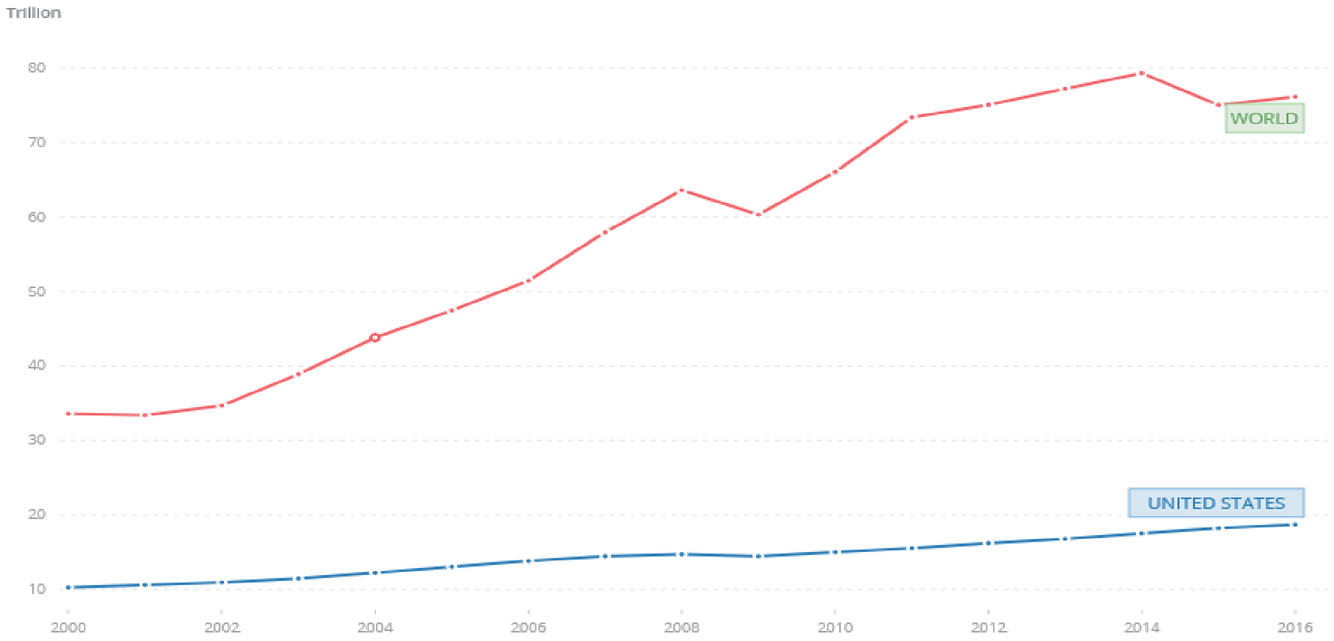
Comparative analysis of materials consumption between the USA and the World

Figure 1: Population Total, World and the USA, 2000-2016



Source: World Bank Open Database, 2020

Figure 2: GDP Current(US) World and USA, 2000-2016



Source: World Bank Open Database, 2020

Population growth and GDP are key drivers of materials consumption. They influence human demand on the environment and are useful for explaining the differences observed in materials consumption. Therefore, prior to discussing and analysing materials consumption between the World and the USA, it is essential to briefly review the data on the aforementioned indicators as they will inform the analysis of materials consumption.

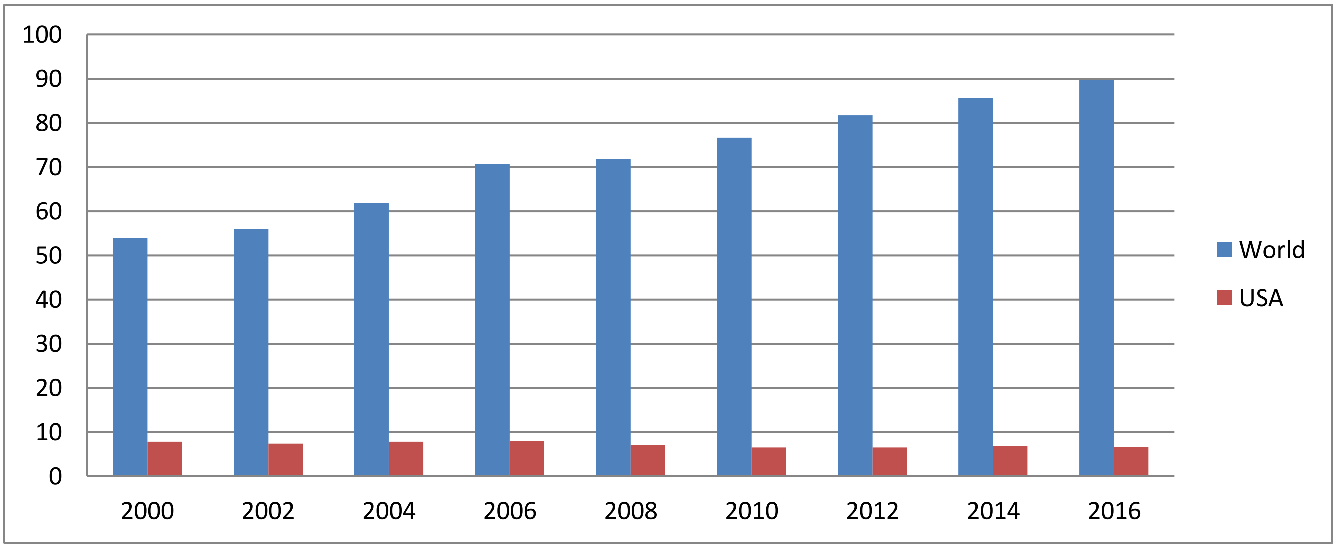
Figure one presents the population data of the World and the USA for the period 2000 to 2016. The data presented by the graph indicates that World's population has been increasing significantly while the population of the USA seems to be flattened over the period observed. The increase in the World's population might have been driven by population growth in Asia, Latin America, Europe and Africa (Schandl et al., 2017). India and China account for the largest share of the World's population. The USA's population dynamics seem to be influenced by economic indicator. After the 2008 financial crisis, the USA's population start to increase, and the same trend was observed following the global recession in the 1930's.

Figure two compares GDP in the USA with the rest of the World. The GDP data covered the period 2000 to 2016 and was obtained from the World Bank Open Data Portal. World's GDP has been increasing faster than the USA for the period observed. Growth in GDP current in the USA has been gradual but consistent. Growth in the world's GDP might have been influenced by the astronomical growth in China, Japan, India, and other Latin American countries (Schandl et al., 2017). Also, during the period observed, Africa experienced growth in GDP and hence, contributed to the global increase in GDP. Developments in transition and developing countries across the world and the improvements in international and global trade contributed to the rise in global GDP (Schandl et al., 2017).

The data presented by both figures suggest that both population and GDP have been increasing consistently and sharply across the world while increasing slightly in the USA. Increasing population and GDP growth represents an increase in the need for natural resources (Schandl et al., 2017). It also projects an increasing human demand on the environment and the rising competition for resource use. Managing the increasing competition and demand for resources is a critical policy agenda for governments and the world at large as resource depletion is increasing globally.

Having discussed the pattern of two key factors of environmental pressure, it is essential to closely analyse the materials consumption between the USA and the rest of the world for the same period that data on GDP growth and population was obtained. Reviewing the materials consumption pattern with GDP and population growth data will add depth and quality to the analysis and discussions as the latter are key factors that influence human demand on the environment. Below are additional figures and tables that provide relevant information on materials consumption.

Figure 3: DE Total World and USA, 2000-2016



Source: UNEP Open Database, 2020

Table 1: DE by material type in the USA

Description	2000	2002	2004	2006	2008	2010	2012	2014	2016	2017
Biomass in billions	1.4	1.3	1.5	1.5	1.5	1.6	1.5	1.7	1.7	1.7
Fossil Fuel in billions	1.7	1.7	1.7	1.7	1.8	1.7	1.8	1.9	1.9	1.9
Metal Ores in millions	774	632	603	606	619	560	584	618	601	593

Source: UNEP Open Database, 2020

Table 2: DE by material type in the World

Description	2000	2002	2004	2006	2008	2010	2012	2014	2016	2017
Biomass in billions	16.4	16.8	18.0	18.7	20.2	20.7	21.4	22.6	23.6	24.1
Fossil Fuel in billions	9.9	10.3	11.9	12.2	12.9	13.5	14.2	14.4	14.7	15.0
Metal Ores in billions	4.8	4.8	5.6	5.9	6.5	7.1	7.9	8.2	8.8	9.1

Source: UNEP Open Database, 2020

The third figure presents data on domestic extraction total for the USA and the rest of the world in billions of tonnes covering the period 2000 to 2016. The data presented by the graph reveals similar pattern of GDP and population growth between the USA and the rest of the world. Materials extraction across the world showed an increasing pattern while materials extraction in the USA revealed a declining pattern for the period observed. The increase in global material use is consistent with the finding of Schandle et al. (2017). This suggests that human demand on the environment increased across the world while human demand on nature decreased in the USA during the same period.

The statistical data (table 1) shows that the fastest-growing material in the USA during the period 2000 to 2017 is biomass. Biomass increased in the USA from 1.4 billion tonnes in 2000 to 1.7 billion tonnes in 2017. Following biomass is fossil fuel which increased from 1.7 billion tonnes in 2000 to 1.9 billion tonnes in 2017. The data shows that metal ores have been declining during the same period.

The data (table 2) reveals that biomass is also the fastest-growing material globally. Biomass increased from 16.4 billion tonnes in 2000 to 24.1 billion tonnes in 2017 globally. Fossil fuel is the second highest material consumed globally during the same period. Fossil fuel increased from 9.9 billion tonnes in 2000 to 15 billion tonnes in 2017. The extraction of metal ores also increased during the same period globally. However, the quantity of metal ores extracted globally is lesser than biomass and fossil fuel.

Overall, the research reveals that biomass was the fastest-growing material both in the USA and globally during the period 2000 to 2017. While the extraction of metallic materials declined the USA during the period 2000 to 2017, the extraction of metallic materials increased globally during the same period. The research indicates that the rising need for energy in several parts of the world to facilitate manufacturing and industrial activities influenced the demand for biomass and fossil fuel globally. This finding supports earlier research conducted by Schandl et al. (2017).

Logarithmic decomposition of material consumption

In order to assess the drivers of material consumption in the USA and the rest of the world, the IPAT equation was employed. A logarithmic decomposition of the data for material consumption in the USA and the rest of the world was conducted covering two sub-periods, 2000-2010 and 2010-2017. Below is a table that provides the results of the IPAT equation and logarithmic decomposition.

Table 3: Logarithmic Decomposition of material use between the USA and the World

USA	2000-2010	2010-2017	World	2000-2010	2010-2017
P	9.18%	4.94%	P	12.41%	8.15%
DMC/GDP	-57.00%	-31.10%	DMC/GDP	-32.55%	-1.99%
GDP/P	28.81%	21.27%	GDP/P	55.21%	12.21%
DMC	-19.01%	-4.89%	DE	35.06%	18.37%

Source: Author's own calculation

Table 3 reveals the individual contribution of the key drivers of material consumption in the USA and the rest of the world for two sub-periods, 2000 to 2010 and 2010 to 2017. The table shows that during the period 2000 to 2010, the income or affluence, represented by GDP per capita was the lead driver of material use in the USA. Income recorded the highest individual contribution to material use in the USA followed by population growth. Interestingly, the technological coefficient is negative, thus suggesting that improvements in material efficiency mitigated some of the growth of material use. This finding supports earlier findings by Schandl et al. (2017) who found negative technological coefficient in some parts of the world, especially North America and Europe.

For the rest of the world, the table shows that income was the lead driver of material consumption globally during the period 2000 to 2010. Population growth was the second highest contributor to material consumption globally during the period 2000 to 2010. Material intensity or technological coefficient was also negative, thus indicating that improvements in material efficiency mitigated the growth of material consumption globally. This finding confirms earlier findings by Schandl et al. (2017) who found negative technological coefficient in parts of the globe.

For the period 2010 to 2017, during which further decline in material consumption was observed in the USA, the logarithmic decomposition of the individual drivers of materials use reveals that income was the lead driver of material consumption in the USA. Income recorded the highest percentage in terms of individual contribution to material consumption followed by population growth. However, it should be noted that the contribution of income and population to material consumption in the USA declined during 2010 to 2017. Again, table 3 shows that technological coefficient is negative, which suggests that improvements in material efficiency in the USA mitigated the growth in material consumption during the period, 2010 to 2017. It is important to mention that the impact of the negative technological coefficient on material consumption outpaced the impact of population growth and economic growth thus leading to reduction in material consumption in the USA.

During the period 2010 to 2017, table 3 further reveals that the key driver of material consumption in the global economy was income. Population growth also contributed to the increase in material use globally and recorded the second highest contribution to material consumption after income. As it is the case with the USA, the contribution of income and population growth to material consumption in the global economy reduced during the period 2010 to 2017. The table reveals significant decline in the contribution of technological coefficient to mitigating growth in global material use.

Overall, the logarithmic decomposition of the drivers of material use in the USA and the globe reveals that material consumption was driven by economic growth represented by GDP per capita and population growth during the period 2000 to 2017. Growth in income was the lead driver of material consumption followed by population growth. Notably, table 3 reveals that improvements in material efficiency mitigated growth in material use during the period 2000 to 2017, although improvements in material efficiency declined during the period 2010 to 2017. Developments in infrastructure, communication and transport network in Asia and other emerging countries during the period 2010 to 2017 contributed to the decline in material efficiency (Schandl et al., 2017).

DISCUSSION OF THE RESULTS

The increase in materials extraction across the world can be explained by the rise in population and income across the world. The global economy has expanded significantly, and population almost doubled as revealed by the data presented in the figures 1 and 2 and further validated by the logarithmic decomposition of the key drivers of environmental pressure. The globe has experienced a considerable acceleration in material use since 2000 (Schandl et al., 2017). Developing and transition countries that basically trade in primary resources including the explosion of the manufacturing industry in China, India, Japan and the Asian tigers significantly contributed to the increase in the world's total domestic materials extraction. Also, urbanization and increase in labor force participation influenced growth in materials extraction globally as new economies and developing countries undergo structural changes which require the use of significant amounts of primary materials. Several studies (Schandl et al., 2017; West and Schandl, 2013; Schandl and West, 2012) found evidence that revealed that growth in global material use was affected by material demand in Asian economies, Latin America and Africa.

The data and findings of this research support the thesis or conclusions of Teixidó-Figueras et al. (2016), which argued that income drives environmental pressure. Economic trends and resource use were closely linked globally as the data shows. Although global material demand declined in 2008 and 2009 due to the global financial crisis, global material demand has rebounded with strong growth trajectory (Peters et al., 2012). The findings suggest a positive relationship between income and population growth and environmental pressure across the world for the period under review. The research finding also confirms earlier findings by Schandl et al. (2017) in which growing population and economic growth were considered as the key drivers of material use.

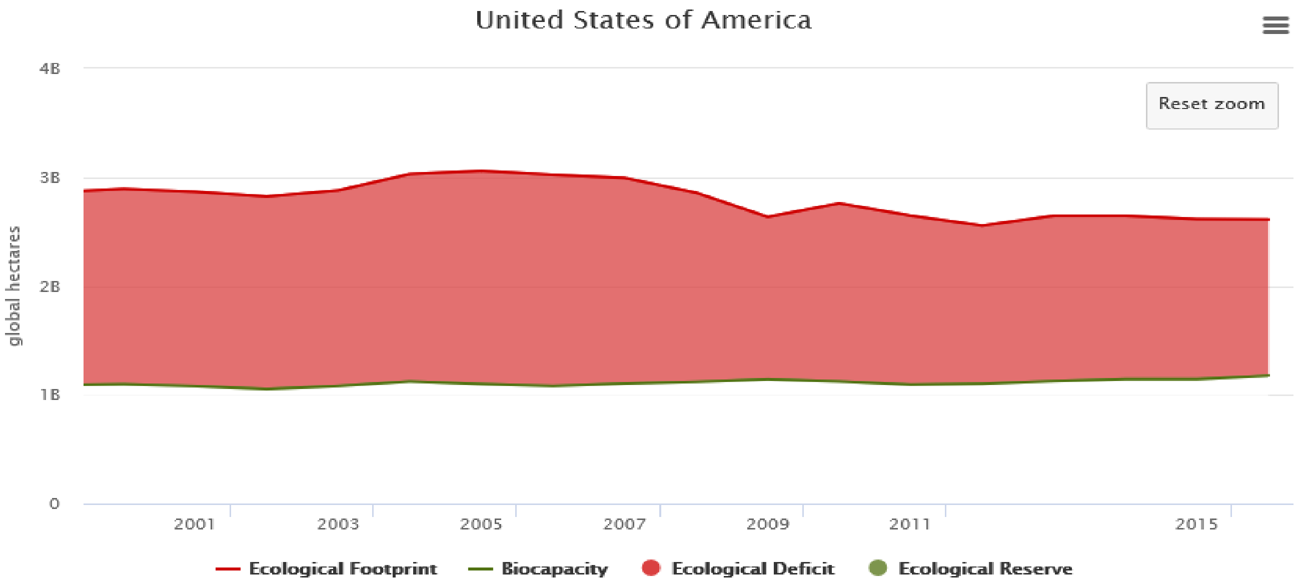
As it is the case with the globe, income was also the lead driver of material use in the USA during the period 2000 to 2017. Population growth also contributed to material use in the USA during the same period. While technological advancements or material efficiency mitigated the growth of material use in the USA, population and economic growth increased environmental pressure. However, the effects of technological advancement overshadowed the effects of population and economic growth on material use leading to a decline in material consumption in general in the USA during the period 2000 to 2017. The findings therefore validate the argument and findings of Teixidó-Figueras et al. (2016).

Generally, income or economic growth was the key driver of material use in the global economy and in the USA during the period 2000 to 2017. Population growth especially in Asia and other emerging economies contributed significantly to the rise in material use globally. This finding is also consistent with earlier research findings (Schandl et al., 2017; Schandl and West, 2010). Advancements in technology tended to mitigate the growth in material use both in the USA and the rest of the world thus indicating that investments in green technology were rising both in the USA and the global economy. However, material efficiency declined during the period 2010 and 2017, largely driven by developments in transport, communication and infrastructure networks in material-intensive economies such as China, India and Southeast Asia (Schandl et al., 2017), thus leading to a rebound of material consumption globally.

Ecological Footprint data and analysis

Ecological Footprint data and analysis is very essential for policy makers and governments as such analysis inform the development of policies for strengthening bio-capacity and reducing the impacts of human activities on the environment. Data on ecological footprint total and per capita was obtained for the USA and the global economy. The unit of measurement for ecological footprint and bio-capacity is global hectares (gha). The data covered the period 2000 to 2016 and provides essential information on the trend of ecological footprint and bio-capacity between the USA and the rest of the world. The data was obtained from the Global Footprint Network which publishes the National Footprint Accounts for over two hundred countries.

Figure 4: Ecological Footprint



Global Footprint Network, 2019 National Footprint Accounts

Table 4: Global hectares in billions for two sub-periods in the United States of America

Description	2000	2010	2000-2010	2010	2016	2010-2016
Ecological Footprint	2.9	2.8	-0.1	2.8	2.6	-0.2
Bio-capacity	1.0	1.1	0.1	1.1	1.2	0.1

Source: Author's calculation of data from the Global Footprint Network

Figure4 provides data on total ecological footprint and bio-capacity in the USA for the period 2000 to 2015. The data reveals that ecological footprint in the USA has been fluctuating during the period. An increase in the ecological footprint is noted during the period 2003 to 2009 in the USA. Since 2009, ecological footprint in the USA has been declining gradually.

Bio-capacity on the other hand, has been on the rise steadily. Although the growth rate of bio-capacity was below the growth rate of ecological footprint, the rise in bio-capacity reflects improvements in environmental conservation. Overall, ecological footprint exceeded bio-capacity in the USA which means the USA experienced ecological overshoot during the period 2000 to 2015. This finding is consistent with the finding of earlier studies (Lin et al., 2018; Schandl et al., 2017).

From the data, the fastest growing ecological footprint component is built-up land which increased from 192 million gha in 2000 to 292 million gha in 2015. The next fastest-growing footprint component is fishing ground, followed by crop land. The finding suggests that human demand for built-up land increased during the period 2000 to 2015 in the USA while carbon usage and the use of forest products declined during the same period.

The dataset also reveals changes in bio-capacity components. Built-up land was the fastest growing component of bio-capacity followed by fishing grounds and crop land. During the period 2000 to 2015, built-up land experienced the highest growth and matches the ecological footprint requirements for built-up land. Given that built-up land component of bio-capacity matches the ecological footprint requirements for built-up land, human demand for built-up land will be met by the environment.

The data (table 4) shows that ecological footprint in the USA declined by 0.1 billion gha between 2000 and 2010. During the same period, bio-capacity increased in the USA by 0.1 billion gha. During the period 2010 and 2016, ecological footprint declined further in the USA by 0.2 billion gha. On the other hand, the data shows a rise in bio-capacity in the USA during the period 2010 and 2016. Bio-capacity increased in the USA by 0.1 billion gha during the same period.

The further decline in ecological footprint during the period 2010 and 2016 suggests that as the USA recovers from the global financial crisis and productivity in the service sector improves, human demand on the ecosystem reduces (Schandl et al., 2017; Lin et al., 2018). The decline in ecological footprint was driven by decline in population growth during the same period. On the other hand, the upsurge in bio-capacity in the USA was influenced by improvements in resource management, agricultural yields and use in the USA.

Figure 5: Ecological Footprint

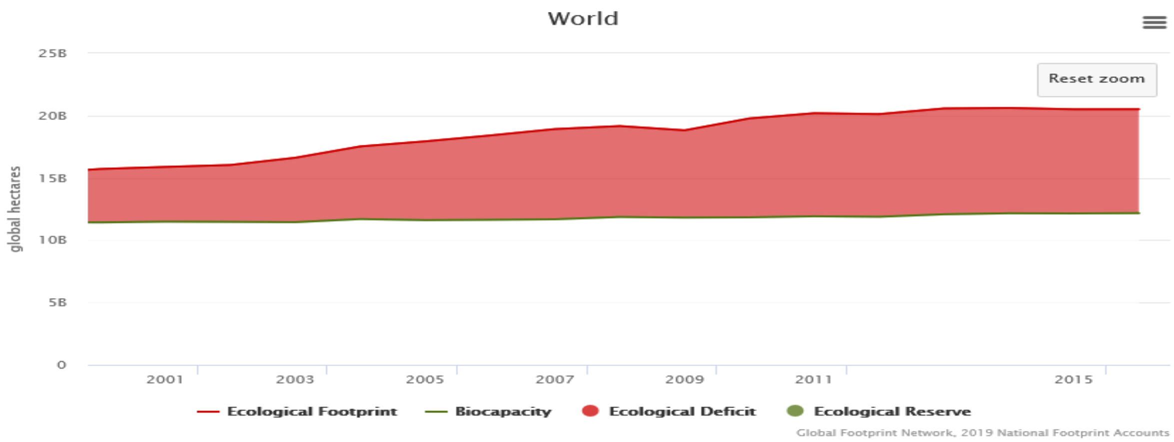


Table 5: Global hectares in billions for two sub-periods in the World

Description	2000	2010	2000-2010	2010	2016	2010-2016
Ecological Footprint	15.8	19.8	4	19.8	20.5	0.7
Bio-capacity	11.4	11.8	0.4	11.8	12.2	0.4

Source: Author's calculation of data from the Global Footprint Network

Figure5 provides data on the total ecological footprint and total bio-capacity of the global economy. The data covered the period 2000 to 2015 and shows that ecological footprint increased globally during the aforementioned period. The rise in global ecological footprint accelerated from 2010 and has been steady until 2015. Global ecological footprint increased from 15.7 billion gha in 2000 to 20.5 billion gha in 2015. These results corroborate earlier research findings (Lin et al., 2018; Schandl et al., 2017).

Total bio-capacity has been on the rise in the global economy. Also, the increase in bio-capacity is shown to have accelerated following the global financial crisis (Lin et al., 2018). Global bio-capacity increased from 11.4 billion gha in 2000 to 12.2 billion gha in 2015. However, the increase in ecological footprint outpaced the increase in bio-capacity suggesting that the planet experienced ecological overshoot during the period 2000 to 2015. This finding is consistent with the finding of Lin et al. (2018) who found that ecological footprint is increasing more than bio-capacity globally.

The dataset further reveals that carbon footprint is the fastest-growing ecological footprint globally. This finding confirms the finding of Lin et al. (2018). Carbon increased from 8.7 billion gha to 12.3 billion gha in 2015 globally. After carbon, the next fastest-growing component of ecological footprint globally is built-up land which recorded a 158 million gha increase between 2000 and 2015. The ecological footprint for grazing land decreased during the period by 2 million gha.

In terms of bio-capacity, the fastest-growing component is built-up land. Built-up land increased from 314 million gha to 473 million gha followed by crop land which increased by 88 million gha. Fishing grounds, forest products and grazing land declined during the period 2000 to 2015. This suggests that the earth's capability to meet human demand for fish commodities, forest products and grazing land is diminishing.

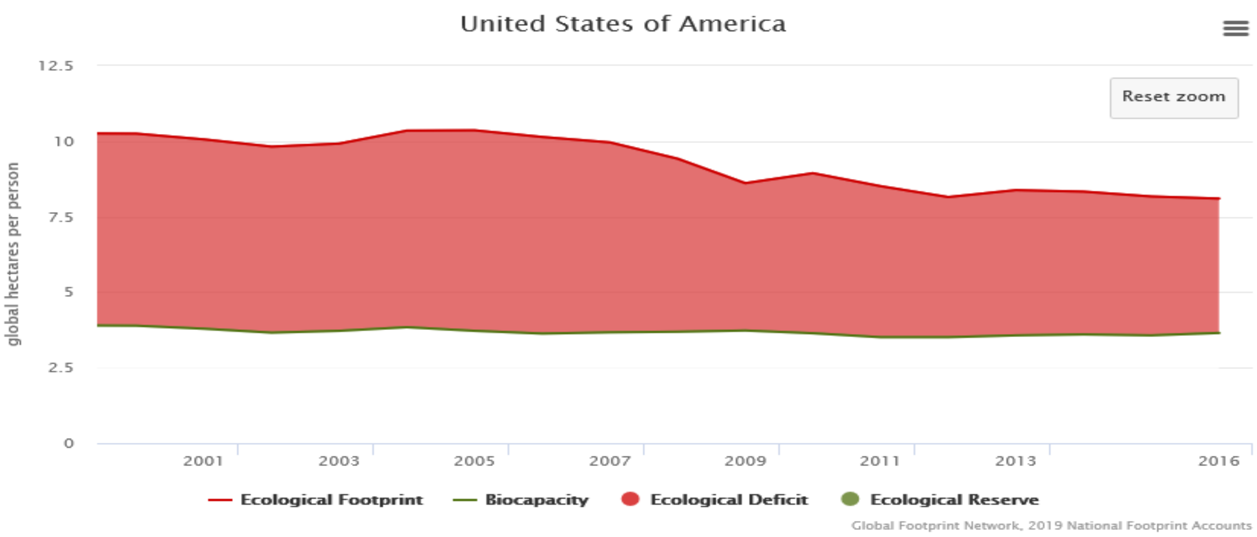
The dataset (table 5) shows a similar pattern of human demand and the use of the ecosystem in the USA and the rest of the world. Ecological footprint increased both in the USA and the global economy during the period 2000 to 2010. While the USA experienced some fluctuations in ecological footprint, the global economy has been experiencing consistent increase in ecological footprint. Ecological footprint increased sharply in the USA and the global economy following the global financial crisis. While the rise in ecological footprint in the USA was in large part dominated by built-up land, the acceleration of ecological footprint in the global economy was supported by the growth in carbon emissions. These results are consistent with the research finding of Lin et al. (2018).

Bio-capacity also increased in the USA and the global economy during the period 2000 to 2010. However, the growth rate of ecological footprint outpaced the growth rate of bio-capacity in the USA as well as the globe. Built-up land was the fastest-growing component of bio-capacity in both the USA and the globe. The data further suggests that both the USA and the global economy are experiencing ecological overshoot, which validate the findings of Lin et al. (2018). Therefore, policy actions are needed to reduce human demand on the environment while at the same time improving the productive capacity of the ecosystem.

It is essential to mention that ecological footprint is driven or influenced by population growth and GDP growth (Niccolucci et al. 2007; Bastianoni et al., 2013). The increase in ecological footprint globally was driven by China and other emerging countries where population growth was rising (Galli et al., 2012). During the period 2000 to 2016, the USA and the global economy experienced growth in population and GDP. However, the population growth and GDP growth across the world was very significant and steady than the USA. The population growth rate and GDP growth rate across the world was high as compared to USA during the same period. But the world's population grew higher than GDP during the same period.

From a review of the data, the rise in ecological footprint in the USA and the global economy was driven by population growth and GDP growth. The growth in population added more human pressure on the ecosystem requiring more productive areas. Growth in GDP increases human demand on the environment (Niccolucci et al., 2007). Population growth is considered to be the biggest driver of ecological footprint during the period 2000 to 2016 as the growth rate of population exceeded the GDP growth rate globally during the same period. Lin et al. (2018) also found evidence that corroborate the above results.

Figure: 6 Per Capita Ecological Footprint



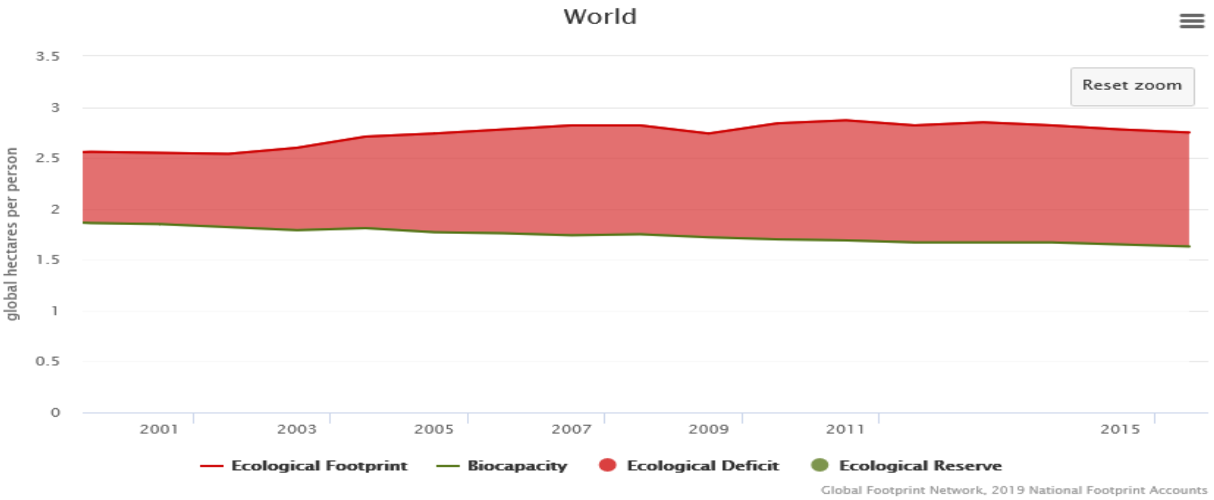
Global Footprint Network, 2019 National Footprint Accounts

Figure6 shows the trend of per capita ecological footprint and bio-capacity of the USA for the period 2000 to 2016. Per capita ecological footprint in the USA has been declining of late. An increase in per capita ecological footprint is observed during the period 2004 to 2008. However, the increase was not significant and steady as the per capita footprint has been declining gradually although small increases were noted following the financial crisis. This result is consistent with the finding of Lin et al. (2018).

As per capita ecological footprint declined, per capita bio-capacity also declined during the same period. Per capita bio-capacity declined from 3.8 gha in 2000 to 3.6 gha in 2016. Although the rate at which per capita bio-capacity declined is lower than the declining rate of per capita ecological footprint, overall, per capita ecological footprint exceeded per capita bio-capacity in the USA. Hence, the USA experienced ecological overshoot. This finding also confirms earlier research finding of Lin et al. (2018).

The statistical data on the components of per capita ecological footprint shows that crop land was the fastest-growing component. Crop land increased by 0.151 gha from 2000 to 2016. Carbon, forest products and grazing land decreased during the same period. The data suggests that individual human demand or consumption of crop land increased during the same period.

Figure:7 Per Capita Ecological Footprint



Global Footprint Network, 2019 National Footprint Accounts

Figure7 provides insight on the trend of per capita ecological footprint and bio-capacity of the globe for the period 2000 to 2015. The graph indicates that per capita ecological footprint has been gradually increasing globally. Notable increases in the per capita ecological footprint were observed during the period 2010 to 2011. The upsurge in per capita ecological footprint has been consistent globally since the end of the financial crisis. This finding does not support earlier research finding of Lin et al. (2018) in which per capita ecological footprint declined globally.

In terms of per capita bio-capacity, the global economy experienced a slight decline during the period 2000 to 2015. Per capita bio-capacity declined from 1.8 gha in 2000 to 1.6 gha in 2015. While per capita ecological footprint increased globally, per capita bio-capacity decreased, thus suggesting that ecological overshoot increased in the global economy. This finding validates the findings of the research conducted by Lin et al. (2018).

From a review of the statistical data, carbon was the fastest-growing component of per capita footprint globally. Carbon increased by 0.225 gha and is followed by crop land and built-up land. Fishing grounds, forest products and grazing land declined during the period. The data thus indicates that per capita demand for carbon was the key driver of per capita ecological footprint in the global economy.

In comparison with the USA, per capita ecological footprint declined in the USA while it increased globally during the period 2000 and 2016. The difference in the per capita ecological footprint pattern between the USA and the global economy can be attributed to disparities in the population and GDP growth rate between the USA and the world. The sharp population growth experienced in China and other emerging economies influenced the rise in per capita ecological footprint in the global economy (Galli et al., 2012; Myers and Kent, 2003).

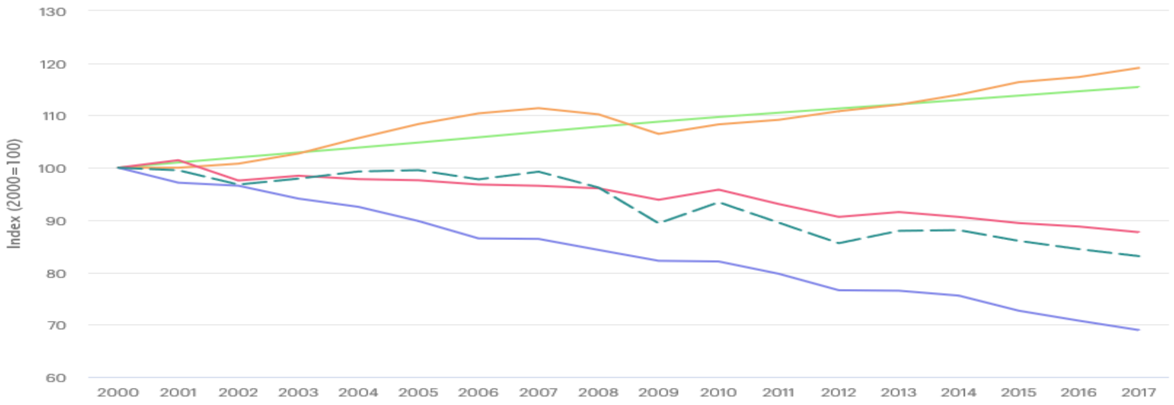
Both USA and the global economy experienced decline in per capita bio-capacity during the period 2000 to 2016. The decline in bio-capacity and the concomitant increase in per capita ecological footprint reflect an increasing global bio-capacity deficit and ecological overshoot. The increasing bio-capacity deficit also indicates that material intensity is increasing across the globe. Material intensive production processes and unsustainable consumption of resources especially in Asia and Africa are influencing the increasing global per capital bio-capacity deficit. Additionally, population growth in China and India and other emerging countries play a key role in driving up bio-capacity deficit globally. These results are consistent with earlier findings of Lin et al. (2018) and Galli et al. (2012).

Carbon emissions data and analysis

Carbon emissions is one the key pollutants of the earth's atmosphere. CO_2 is used to measure the carbon emissions into the atmosphere. In order to examine the trend and impacts of carbon emissions on the atmosphere and the environment, data on CO_2 emissions was obtained for analysis. The analysis will also inform policy development and implementation aim at enhancing sustainable management and use of carbon resource.

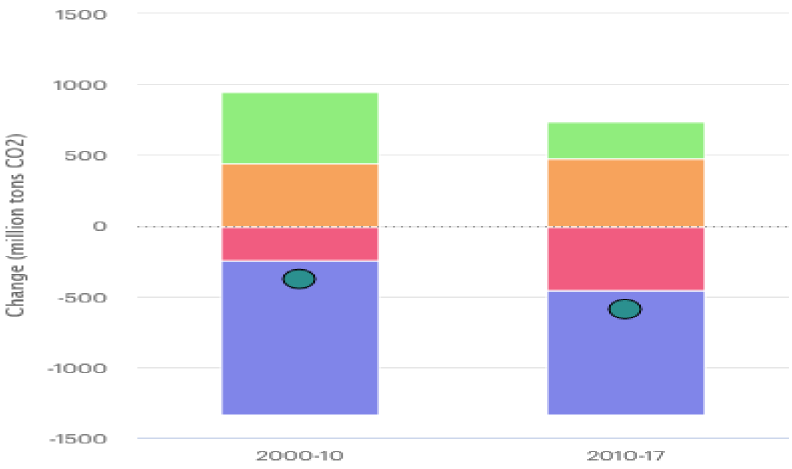
Below are figures that present data on CO_2 emissions for the USA and the rest of the world. The data covered the period 2000 to 2017 and represent the latest data available for CO_2 emissions. The data was obtained from the International Energy Agency (IEA) which publishes annual data on CO_2 emissions for more than one hundred countries.

Figure: 8 CO_2 Emissions, USA



Source: IEA, 2020 Blue: CO_2 emission Green: Population Orange: GDP PPP/Population

Figure:9 CO_2 Emissions in two sub-periods, USA



Source: IEA, 2020 Blue: CO_2 emission Green: Population Orange: GDP PPP/Population

Figure8 shows the trend of CO_2 emissions for the USA. The data presented by the graph covered the period 2000 to 2017 and was obtained from the International Energy Agency. The figure reveals that CO_2 emissions declined in the USA during the period 2000 to 2017. A review of the data indicates that CO_2 emissions declined from 100 million tonnes in 2000 to 83 million tonnes in 2017 in the USA. The reduction in the CO_2 emissions is a positive signal for environmental sustainability in the USA and the result supports earlier reports and studies (EC Report, 2005; Wagner, 2004) that found evidence that project a declining trend in carbon emission due to investment in energy-efficient technologies.

Figure 8 also provides information on population and GDP per capita in PPP terms for the period 2000 to 2017. Population and GDP per capita in PPP terms have been on the increase in the USA during the period 2000 to 2017. Decline in GDP per capita in PPP terms is observed during the period 2008 to 2010, at which time, the world experienced a global financial crisis. Following the financial crisis, GDP per capita in PPP terms has been on the rise and has remained steady and consistent. Population during the same period has been increasing and has remained steady.

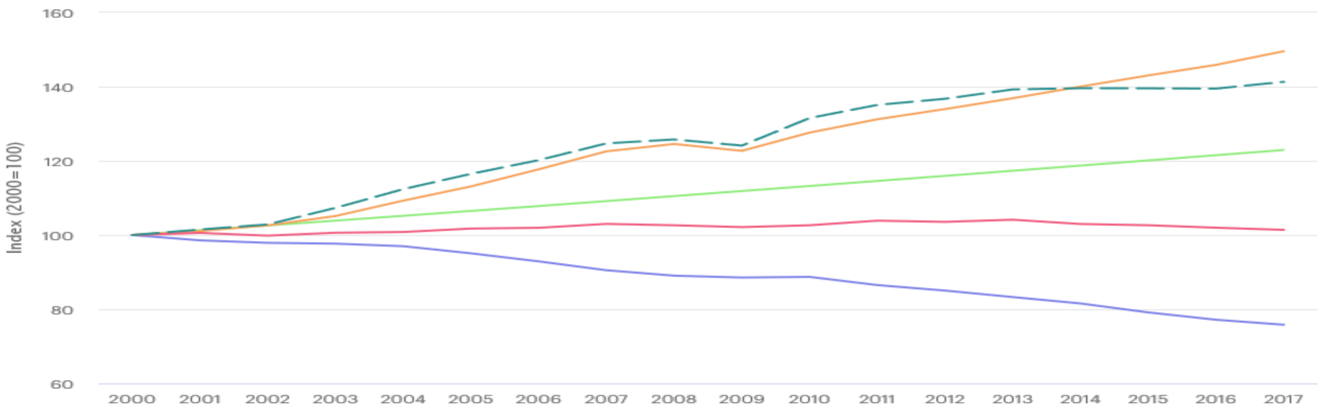
The data further suggests that while CO_2 emissions were declining, population and GDP per capita in PPP terms were increasing in the USA. An inverse relationship is observed between CO_2 emissions and GDP and population growth during the period 2000 to 2017. The data and findings provide new evidence for analysing the relationship between carbon emissions and population and GDP growth as the finding does not support initial research conclusions or finding (IEA, 2020; Lin et al., 2018).

IEA (2020) noted that the key drivers of carbon emissions are population growth, GDP growth and energy supply. Population growth is expected to increase human demand for carbon and hence, ratchet up CO2 emissions. Growth in GDP is projected to increase carbon emissions as economic activities especially industrial activities require the use energy and hence, CO_2 emissions (IEA, 2020).

The data on CO_2 and population and GDP showed a different relationship in the USA for the period 2000 to 2017. The inverse relationship observed between CO_2 emissions and population and GDP growth in the USA can be explained by several factors. Firstly, it should be noted that the service sector, which does not consume much CO_2 as compared to the industrial sector, is the key driver of economic growth in the USA. Secondly, the USA pursued offshore production strategy, shifting material intensive production outside the USA (Schandl et al. 2017). Thirdly, energy-efficient technologies contributed to the decline in carbon or fossil fuel consumption in the USA.

Graph nine shows that during the period 2000 to 2010, the decline in carbon emission was lower than the period 2010 to 2017. The rise in the declining rate of carbon emission after 2010 in the USA could be attributed to diminishing industrial activities and the decline in commodity prices occasioned by the global financial crisis. Other studies (Schandl et al., 2017; Lin et al., 2018) on global material use found similar evidence suggesting that material use declined during the period 2010 to 2017. Additionally, the rise in the service sector's contribution to GDP growth following the financial crisis contributed to the reduction in the demand for carbon in the USA. This result supports earlier report and projection of carbon usage (EC Report, 2015; Wagner, 2004).

Figure: 10 CO_2 Emissions, World



Source: IEA, 2020 Blue: CO_2 emission Green: Population Orange: GDP PPP/Population

Figure: 11 CO_2 Emissions in two sub-periods, World

Source: IEA, 2020 Blue: CO_2 emission Green: Population Orange: GDP PPP/Population

Figure10 shows the pattern of CO_2 emissions in the global economy for the period 2000 to 2017. The statistical data on CO_2 emissions was obtained from the IEA and represents the latest statistics on CO_2 emissions globally. The graph shows that carbon emissions rose gradually in the global economy during the period 2000 to 2017. However, decline in carbon emissions in the global economy is observed only during the global economic crisis which negatively affected commodity prices. Following the crisis, carbon emission increased consistently and steadily in the global economy. This finding is also consistent with previous research findings on material use (Peters et al., 2012; Schandl et al., 2017 and Lin et al., 2018).

Figure 10 also shows the trend of population and GDP per capita in PPP terms in the global economy. From the graph, it is noted that both population and GDP per capita in PPP terms have been rising globally during the period 2000 to 2017. Although GDP per capita in PPP terms declined during the global financial crisis, it rebounded and has since been on the rise following the end of the crisis. Population, on the other hand, has grown steadily and consistently during the period 2000 to 2017 in the global economy.

A review of the data further shows that CO_2 emissions, population and GDP per capita in PPP terms rose in the global economy during the period 2000 to 2017. This data suggests a positive relationship between carbon emissions and population and GDP growth globally thus validating the thesis of the IEA (2020). The growth in population and GDP is noted to have influenced the rise in CO_2 emissions globally. GDP per capita in PPP terms grew higher than population and is therefore considered the key driver of the rise in carbon emissions in the global economy.

It is essential to state that the growth in the world's population and GDP per capita in PPP terms was largely driven by economic transformation in emerging countries. Increase in population and economic activities in China and India observed during the period also contributed significantly to the rise in carbon emissions (Galli et al., 2015; Schandl and West, 2010; Peters et al., 2012). Furthermore, changes in transition economies and rise in industrial activities in Asia, Latin America and Africa also fuelled the rise in carbon emissions globally; and the finding is consistent with the results of earlier research (Galli et al., 2012; Peters et al., 2012).

In comparison with the USA, it is noted that while carbon emission declined in the USA, carbon emissions increased in the global economy during the same period. The different pattern of carbon emission observed between the USA and the world during the period 2000 to 2017 is a result of differences in the structure of the economy of the USA with other countries and regions. While economic growth in the USA was driven by the service sector, economic activities in large part of the world were driven by industrial and manufacturing activities (Schandl and West, 2010; Peters et al., 2012). Also, the offshore production strategy pursued by the USA shifted intensive materials use including carbon to other countries, where large manufacturing activities, resources and cheap labour are abundant. This finding is supported by research work conducted by Schandl et al. (2017).

A similar pattern of carbon emissions is observed between the USA and the rest of the world when the data is disaggregated into sub-periods (2000-2010 and 2010-2017). Carbon emission was high in the USA and the global economy during the period 2000 to 2010. Following the global financial crisis, carbon emission reduced in both the USA and the world during the period 2010 to 2017. The reduction in carbon emission was driven by the imposition of cap on carbon emission, advancement in green and energy-efficient technologies and falling trade flows (EC Report, 2015; Peters et al., 2012; Schandl et al., 2017)

The similarity in the pattern of carbon emission observed between the USA and the rest of the world in the two sub-periods reflects the effects of the global financial crisis and the increasing investment in green technology both in the USA and several parts of the world. The global financial crisis slowed down global economic activities thus reducing demand for carbon. The reduced demand for carbon and the reduction in global trade and commodity prices affected the USA and several countries in the world leading to a reduction in carbon emissions in the USA and the globe (Schandl and West, 2010; Schandl et al., 2017). During the period 2010 to 2017, significant investments in green technology were made in the USA and across the world in response to increasing pressure from environmental conservationists including the introduction of carbon trading in some parts of the globe. These investments reduced the use of carbon in the production of energy in the USA and the global economy, thereby leading to a decline in carbon emission. These results are supported by the study conducted by Steinberger and Roberts (2010).

CONCLUSIONS

The analysis conducted produced more reliable and robust findings on resource use and management in the USA and the global economy. Overall, resource use declined in the USA during the period 2000 to 2017 while it increased in the global economy during the same period. Following the financial crisis, the decline in resource consumption accelerated in the USA and the global economy while bio-capacity increased. In spite of the rise in bio-capacity and the decline in resource use following the global crisis, the USA and the world is experiencing ecological overshoot thereby suggesting the need for strong policy actions by governments across the world (Schandl et al., 2017).

The analysis identified several drivers of resource use globally. The principal drivers of the rise in resource demand and consumption globally include population, economic growth and urbanization. China, India, Japan and the Asian tigers played a considerable role in the rise in global resource use as these economies experienced significant growth and structural changes requiring the intensive use of natural resources. The rising number of consumers and the middle class in emerging economies also contributed to the rise in resource use in the global economy leading to the earth experiencing ecological overshoot (Yuk-Ha Tsang, 2014; Myers and Kent, 2003).

The analysis established that carbon, fossil fuel and biomass were the fastest-growing materials globally. The rise in the demand and consumption of fossil fuel, carbon and biomass was influenced by the need for more energy to facilitate industrial activities which were on the increase in emerging economies including China, Japan and Latin America. Global economic activities were driven by industrialization which required the supply of energy and hence, led to the rise in the demand and consumption of carbon, biomass and fossil fuel. Therefore, strong policy actions are needed to balance the quest for economic growth and the need to conserve the environment.

Interestingly, the decline in resource use in the USA was not accommodated by a decline in income or economic activities and population growth. Undoubtedly, GDP and population have been on the increase albeit slowly while human consumption of natural resources has been declining. The decline in resource use in the USA was driven by several factors including advancement in technology and innovation that enabled improvements in material efficiency (Schandl et al., 2017) and the use of offshore production strategies and trade fragmentation. With increasing competition globally for control and use of resources, the decline in resource use in the USA was an essential step toward enhancing environmental conservation and ensuring the availability of resources for the use of future generation.

The results obtained from the data and the analysis support earlier findings adduced by Teixidó-Figueras et al. (2016), Schandl et al. (2017), Lin et al. (2018) and Schandl and West (2010). The analysis found evidence that indicate a strong and positive relationship between income, population, urbanization and environmental pressure. The analysis also established a declining trend in material efficiency globally and increasing human demand that exceeds the regenerative capacity of the environment.

This research therefore highlights that resource sustainability is still a cause for concern globally as the planet is experiencing ecological overshoot. Although efforts are being made to reduce the overuse of resources in the global economy, those efforts need to be accelerated to prevent further environmental depletion and the damages that come with climate change. Resource efficiency is declining and the globe risks not achieving the environmental sustainability targets of the sustainable development goals. The decline in material efficiency globally has detrimental effects and undermines efforts to mitigate major environmental impacts and keep human appropriation within planetary boundaries (Rockstrometal., 2009; Steffen et al., 2015) Therefore, there is an urgent need for the adoption and implementation of stronger environmental protection measures including additional efforts for financing and investment in energy-efficient technology.

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